BASIC ONE LINE CONNECTION DIAGRAMS FOR POWER HOUSES AND SUBSTATIONS

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INTRODUCTION

The accompanying paper on "Basic One Line Connection Diagrams" was presented in absentia before a plenary session of the whole Electrical Apparatus Committee of NELA at Atlanta, Georgia, December 31, 1931. It was a report by a subcommittee on station design of which Mr. A. L. Harding was chairman. The paper was prepared after considerable correspondence with members of the subcommittee and Mr. Harding read it for the author at Atlanta. The discussion which follows the paper indicates the great amount of interest which the subject aroused. Many requests for copies have been received from members of the REA staff and also from outside the organization.

As mentioned in the conclusion of the discussion, some of the statements made were purposely drastic in order to bring out discussion.

As far as is known, this is the only paper of its kind in existence, except possibly a shorter discussion by Phillip Sporn in one of the issues printed but not published by The Association of the Edison Electric Illuminating Companies.

Very little has occurred since the presentation of the paper and the discussion to change any of the statements. It may be mentioned, however, that since that time it was possible to crystallize the fact that, in reality, there are only four basic diagrams. These are shown as Figures Nos. 2, 3, 4 and 5 in the diagrams. All others are built up from these four.

It is only necessary to mention that a dot on a single-line diagram may sometimes represent a connection on a radio set which physically is almost the same as the picture on the diagram, but at other times it may represent a tap on a 3-phase, 263-kv line which would take up a structure perhaps 80 feet high and cost tens of thousands of dollars, to realize the importance of clear and clean single-line diagrams.

Another point of great importance is the fact that any insulator, any foot of conductor, or any other part of the equipment that is not needed should not be there because it represents an unnecessary source of trouble.

Too much time and money is being spent on the assumption of coincidences. Someone assumes that generator No. 1 may be out, and at the same time transformer No. 2, and perhaps switch No. 3, and proceeds to provide complicated switchgear equipment to take care of such coincidences. The fact is that when a coincidence of this kind actually occurs, the operator does not know that he has all that equipment for switching purposes. For an extreme case, that does not occur frequently, it is better to have on hand spare pieces of cable for jumpers than to have complicated switchgear equipment.

Since the presentation of the paper it has become more and more evident that Diagram No. 5 is the most useful of all the diagrams. It is difficult

to conceive of any recurring operation that could be done by any other diagram that could not also be done by this one. Metal clad switchgear, so manufacturers claim, makes it difficult to use this diagram. But the whole metal clad switchgear idea, with complete material handling equipment for each breaker, was developed at a time when breakers were just switches and had a habit of blowing up regularly. Now breakers are pretty reliable. Switch cubicles with gang-operated disconnects are now quite adequate for most conditions.

It is of extreme importance on any power system to try to make all circuits alike so that when anything happens the operator knows what to do quickly.

Those who are not versed in diagrams find it difficult frequently when they see a very complex diagram, whether it be a single-line diagram or a full diagram, to acquire a picture in their own mind of what it is all about. When the circuits are all the same, it is only necessary to visualize one of the circuits to get a complete picture of a power house or a power system. This applied particularly to station auxiliaries in steam plants. Instead of visualizing the whole station auxiliary system, it is much better to visualize the operation and assume that an operator stationed in the proximity of a group of pumps, is in charge of the operation of these pumps and that he is a very important consumer. All that is necessary to do from the viewpoint of the power house is to see that he is supplied with a very reliable source of power. The distribution of power among the various motors in his proximity is merely a small distribution job. There may be several such important consumers in a power house. If this is done, a problem, which in the beginning appears unusually complex and difficult to grasp, becomes very simple.

When preparing diagrams it is of extreme importance not to attempt to draw them geographically. It is much easier to conceive a drawing diagrammatically if it is shown by horizontal and vertical lines without any diagonals, than it is to conceive it if it is shown geographically. Even when a diagram is shown geographically it still does not convey the impression of the importance of a dot on the diagram referred to above.

It is hoped that the paper will bring about additional discussion and assist in the establishment of standardized simple diagrams, saving the operators many unnecessary headaches.

BASIC ONE LINE CONNECTION DIAGRAMS

Electrical Apparatus Committee NELA
Station Design Subcommittee
Subject - Committee on Design Fundamentals

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ELECTRICAL APPARATUS COMMITTEE NELA
STATION DESIGN SUBCOMMITTEE
SUBJECT-COMMITTEE ON DESIGN FUNDAMENTALS

BASIC ONE LINE CONNECTION DIAGRAMS FOR GENERATING STATIONS AND SUBSTATIONS

Basic Conceptions

There are three basic conceptions in electric station design:

1. Diagram conception
2. Space conception
3. Economy conception

These three conceptions must always be kept in mind by anyone who attempts to design electric stations. The conceptions of safety and reliability are incorporated in these three basic conceptions. Since the space requirement and the cost of the station are determined by the diagram to a far greater extent than by any other considerations except the cost of main equipment, the study of the diagram must be our first concern. The conception of the diagram can be subdivided into the following sub-conceptions:

A - Single Line Diagrams

1. Basic diagrams - Typical circuits
2. Station diagrams - built up of a number of basic diagrams
3. System diagrams - built up of a number of station diagrams

B - Full Line Diagrams

1. Main circuits
2. Control circuits
3. Instrument circuits
4. Relay circuits

Historical

From about 1916 to 1929 we had a period of power house and line construction unparalleled in history. Things had to be done on a grand scale and as rapidly as possible, and it is remarkable what an abundance of new and original ideas in station design were brought out during that period in spite of the high pressure under which the designer worked and even in spite of the necessity of obtaining priority rights during the war. We can well be proud of our achievement in station design during the high pressure period of 1916 to 1929; there was hardly a new power house, a new substation, or new line that did not contain some new idea, some improvement over all previous designs. But in the rush of work we often forget that improvement in apparatus and protective devices went hand in hand with

improvements in station design and we often continued to provide precautions that were no longer necessary for the improved apparatus.

The result is a concensus that our switching systems are generally too complicated and unsystematic and that attempts should be made to simplify and clarify station design. But so far these attempts do not systematically come down to fundamental principles, often looking at the whole station as such, the whole forest, instead of systematically studying the basic diagrams, the trees of which the forest consists. Practically all complications are brought about either by the use of too many disconnects or by the use of the necessary disconnects in the wrong place. A well known teacher of medicine has been instructing his students that before prescribing a drug they should make sure that they know at least three reasons for the use of that drug in the particular case, and that they should not prescribe the drug if they did not know three such reasons. It may not be possible to find three reasons for every disconnect, but we should at least have one good reason before we prescribe one. Metal-clad switchgear, factory built, is coming to be more popular and more desirable, and the abundance and variety of disconnect schemes has been a great handicap in the development and standardization of metal-clad switchgear.

It is the purpose of this Committee to come back to earth, to come back to fundamental principles in station design, and we consider it as our first duty to investigate the basic diagrams from which all stations are built up and to attempt to reduce the number of such basic diagrams to a minimum.

It is remarkable that few text books or handbooks or committee reports so far contain a summary of the basic one line diagrams. One attempt at such a summary was contained in an article in the Electrical World of June 4, 1927, entitled "Start Substation Standardization." Figures 1 to 11 inclusive, here presented, are considered to be the basic single line main connection diagrams, certain diagrams containing a parallel symbol for metal-clad switchgear. It is necessary to emphasize that these basic diagrams are the same for low voltage and high voltage, for light duty and heavy duty, for power houses and substations, for station auxiliaries and industrial circuits. Since we are here primarily concerned with diagram conceptions, sizes of breakers, generators or transformers, sizes of insulators and spacings of conductors can be left out of consideration. But it is not amiss, the better to visualize the importance of the simplification of the basic diagrams, to take a fling into space conception only to emphasize that we must always remember that a dot on a single line diagram indicating a connection, may actually represent a set of high tension buses.

Even though the 11 basic diagrams shown here do not at first glance appear to represent an excessive number, when we consider that all our power houses and substations and industrial switchgear are made up of these diagrams, experience has shown and it is generally agreed that it would be desirable and should be possible to reduce the number to perhaps not more than five.

Reasons for Variation

Before proceeding to analyze each of the basic diagrams it is well to first investigate the basic causes of differentiation, and we at once find that as a general proposition there are only three such basic causes:

1. Duplication of breakers
2. Duplication of buses
3. Variety of disconnects

It may be said at once that economic conditions will henceforth make it difficult to provide two breakers per circuit, even if they were economically desirable. Only a careful investigation over a considerable length of time can bring a definite answer to the question if and when a second breaker per circuit represents sound economy. Reasoning alone would seem to indicate that as a general proposition it is not sound engineering for ordinary conditions for the following reasons:

I Breakers are much more reliable than they were in the past.

II There are very few loads left that are supplied by one circuit only, so that it should be possible to take any circuit out of service for inspection or repair without jeopardizing service.

III When there is only one supply circuit, it is necessary to be prepared for shut-downs from line troubles which will be much more frequent than breaker troubles. And if the circuit can stand such shut-downs from line troubles, it should also be able to stand the infrequent shut-downs of short duration for breaker inspection or repair.

These three points should be carefully and thoroughly discussed from all angles. They will be repeated here again and again in connection with by-passes and transfers.

As to bus duplication it would seem necessary to repeat what a bus is, since it seems that many station designers work under a misconception of the term. Just because a line is drawn horizontally at the top of the diagram sheet it is not necessarily a bus. A bus is a main, receiving energy from one or more circuits and supplying energy to one or more circuits. Both incoming and outgoing circuits must be connected to a bus, otherwise it is not a bus. A transfer connection that can only carry one circuit at a time is not a bus. This is all so simple that it should not be necessary to mention it, but there are so many one-bus stations that pass off as two-bus stations because they have a transfer connection that looks like a bus. It is really necessary to re-define the bus. Duplication of buses is not at all the same story as duplication of breakers. A breaker failure on a circuit only affects the one circuit, but a failure on a bus affects all the circuits connected to the bus. Thus it would seem to be logical to advocate two sets of buses for all well designed switchgear groups,

even though here too an investigation over a period of years and many systems should give the best answer. A second bus is generally inexpensive; often a complete second bus with all the necessary disconnects can be had for the cost of one breaker, and a second bus is certainly very handy for dividing load and testing. But it must be emphasized that this refers to a real bus and not a Simon called Peter transfer connection mistaken for a bus.

The indiscriminate use of disconnects is one of the principal reasons for station complication. It must be remembered that a disconnect is only a necessary evil; it is not intended as a main switching device but only as an auxiliary device to isolate or "disconnect" a piece of equipment such as a transformer or a breaker. It is not intended to be used, and should under no circumstances be permitted to be used for breaking a load. Disconnects should only be provided where they are expected to be operated at reasonably frequent intervals. If a disconnection is only required on very rare occasions it would be better not to provide a disconnect at all but to depend on removing a connection bar.

Two theses may be set down before proceeding with an analysis of the various basic diagrams even though some will come forth with the term "apostle of simplicity" as they have in the past. But it is indeed much better to be an apostle of simplicity than an apostle of crazy complexities.

The first thesis is that the tendency in station design should be to make the basic diagrams of all circuits of a station and even of a system identically the same. This will make for easy operation, minimum of mistakes on the part of the operator, easy maintenance, easy replacement, easy extension, and easy repair.

The second thesis is that any device or connection which may be provided for use in emergency only should be so simple, so clear and so accessible, that the operator should not require any time at all for thinking and planning, and that there is the lowest degree of possibility for a mistake. A complicated emergency installation defeats its own purpose.

Basic Main Connection Diagrams

We will now proceed to critically examine the 11 basic connection diagrams encountered in practice. Some of the statements may appear to be over drastic or over emphatic. This is done for the definite purpose of stimulating a thorough airing, a complete open discussion, and of bringing home the necessity of the thorough investigation that the Committee proposes to undertake after the discussion.

Figure 1

Figure 1 represents the simplest imaginable basic diagram. It may be a generator circuit or it may be a feeder circuit supplying a load which receives no energy from any other source. Hence there is no disconnect on the generator or feeder side of the breaker. This diagram has

no parallel in metal-clad because it is not possible to move one half of the breaker out of place and leave the other half in place. This basic diagram should only be used when not another cent is available under any circumstances.

Figure 2

Figure 2 is an extension of Figure 1 in that it contains a disconnect on the feeder side, when the particular load fed by this circuit is also supplied by another circuit. It is also the basic diagram for the simplest form of metal-clad switchgear.

Figure 3

Figure 3 is a one bus, one breaker arrangement with a by-pass. It is a lady with a past. First there were tin cans containing switches in oil. The term "rupturing capacity" had not been invented yet. Then came interconnections, little power houses and substations were connected to systems, and the little tin cans went up like fire crackers every time a sparrow sat on a wire. There was no money for better breakers, in fact the better breakers were not much better. So a disconnect was installed parallel to the breaker, and every time a little tin can went up in a little fire, it was taken out and the disconnect was closed. A disconnect, even though it had no rupturing capacity, at least had some carrying capacity. How many of us today realize that this is the real story of the by-pass. It would be well indeed to "pass it by" for good. The only occasion for such a by-pass would be perhaps a distant, unattended station, where the by-pass can be used for periodic inspection of breakers. But in such stations it should be possible to shut down a circuit at a time for the purpose of inspection. The circuit goes out of its own volition much more often anyhow. Why not investigate such circuits and find out what these by-passes really saved? These by-passes give much trouble in design, construction, and expense, if it is attempted to apply them to metal-clad switchgear. Hence basic diagrams for metal-clad gear containing by-pass switches are omitted in this paper.

Figure 4

Figure 4 is likewise a lady with a past, but a different past. It originated with the first trolley switchboards. D.C. breakers were not very good in those days, not even as good as they are today, and many of them went out of commission after one short. A spare panel was therefore provided, equipped with breaker, switch and meters, and a transfer connection the full length of the switchboard, so that the spare breaker could be used on any feeder in place of the particular feeder breaker. But it could only be used on one circuit at one time. This is precisely the case of the one bus arrangement, with the bus tie, which often is presented as a two bus arrangement. Today, with good breakers, with the possibility of killing any circuit without interrupting service, what is it all for? Why not investigate and find out? This arrangement too can be had as standard metal-clad. But what for?

Figure 5

Figure 5 is certainly the most rational diagram for present day station design. It is a two bus arrangement, with one breaker per circuit and selector disconnects. As to the danger of operating a disconnect under load it is not greater than in Figures 1 and 2, because one selector disconnect will always be open and only one closed, and certainly there is no danger of opening an open disconnect. One bus tie breaker in any one station of a system is sufficient for splitting load or for testing. The second bus is inexpensive even on metal-clad switchgear. In metal-clad gear the segment type make and break disconnect shown is a convenient arrangement.

Figure 6

Figure 6 is or should be known as the Douglas diagram. It has two sets of main buses, but in emergency one of the buses can be used as a transfer connection. A bus tie breaker goes with it. No demand for metal-clad switchgear in this diagram is known to exist and it should not be allowed to. It superimposes Figure 4 on Figure 5 for anybody who wants it for decoration.

Figure 7

Figure 7 superimposes Figure 3 upon Figure 5. It has so many disconnects, offers so many possibilities of error, so many ways of pulling a disconnect under load, that it should be positively condemned as an asylum diagram. If the load is so important, and if the line construction is such that no line is ever lost, there should be money available for two breakers per circuit.

Figure 8

Figure 8 is the aristocrat of basic diagrams. It is as much as any one can desire. It has two buses and two breakers per circuit. No one can object to it when the money is available. But it seldom will be.

Figure 9

Figure 9 is of comparatively recent origin. It has become known as the "one and one-half breaker per circuit" scheme. It makes it possible to have two breakers available for each circuit with a total of only one and one-half as many breakers as circuits. It is obvious that this must result in a rather complicated physical arrangement of switchgear. Whether or not the additional half breaker per circuit pays for itself can only be determined by an accumulation of operating data. For cases where two breakers per circuit are actually needed it is a question if the half breaker will do the service of a full second breaker.

Figure 10

Figure 10 is known as the H-diagram and has been popular in some large city power houses. It provides a pair of selector breakers

feeding a sub-bus which supplies two feeders. The idea is that if a feeder breaker sticks and fails to open, the selector breaker will open, even though in so doing it will kill another feeder. The arrangement, which is generally used on very heavy duty switchgear is naturally very expensive, but perhaps the expense is justified in heavy duty city power houses. It would be well here too to obtain some experience data over a year's or several years' period.

Figure 11

Figure 11 is a very modern child. It is very pretty and very ingenious. It contains exactly as many breakers as there are circuits, and yet each circuit is said to have two breakers at its disposal. This sounds like magic, but it is quite true. For instance, a short circuit on circuit #1 will kick out breakers #A and B, and a short circuit on #2 will kick out B and C. B can be disconnected and circuit #1 supplied from A only and circuit #2 supplied from C only. But there are several weak points in this scheme.

First - each open breaker produces an open ring, resulting in only one supply for each of the two adjoining circuits.

Second - When two circuits not adjoining are out, a third circuit is also out. For instance, if circuits #1 and #3 are out, circuit #2 is also out.

This diagram is therefore not so pretty as it looks. Furthermore, at first glance it looks like a very flexible system, but on close analysis it would seem to have a degree of flexibility equal to zero. A generator or a transformer or a line can feed the various circuits on the ring only if the adjoining circuits at least on one side are intact. If a ring is really needed for synchronizing or other purpose, such a ring can be established with Figure 5 or Figure 8 by merely adding a bus tie breaker at each end of the buses, and here each circuit would be independent of any other circuit. It would seem like a dangerous precedent to get away from the established idea, that a circuit should depend on the bus only and not on any other circuit. Besides, this ring system calls for undesirable complicated relaying, each breaker being tripped by relays on two different circuits.

Metal-Clad Switchgear

NELA Publication #149 of July 1931, a report of the Electrical Apparatus Committee entitled "Guide for Specification Covering Metal-Clad Switchgear" definitely recommends five (5) basic diagrams for metal-clad switchgear. Any basic diagrams that may be accepted as standard should not be only for metal-clad but for all switchgear, because the difference between metal-clad and other switchgear does not lie in the field of diagram conception but in those of space conception and economy conception. As mentioned above, it would be well to reduce the number of basic diagrams to five, but a great deal of water will flow over the various dams of the power

systems before we will be able to agree which five to pick out. The symbol for a breaker in metal-clad switchgear shown in Publication #149 would likewise seem undesirable and another symbol giving a better visualization of the physical arrangement and the direction in which the breaker is removed, would seem to be preferable. However, this is of minor importance, and a matter for the ASA Symbols Committee to settle.

Operating Statistics

The report of the Committee on Electric Switching and Switchgear 1929-1930 of the Association of Edison Illuminating Companies contains an excellent analysis of certain switching schemes. This report attempts to get down to elementary principles. It contains a number of basic diagrams, but does not yet systematically present all the basic diagrams as they are represented here. The opinions expressed in this report on by-passes are diametrically opposite to the opinions presented here. This is as it should be, because only definite expressions of opposing opinions will in time bring out the truth. But it must be remembered that both are opinions based on reasoning and not on accumulations of facts. We are in the habit of poking fun at statistics, but if we have no statistics, what else have we? The Edison report states that questionnaires had been sent out by the Committee to various operating companies and answers received in most cases, but that in practically every case it had been necessary to go back for more definite and specific information. The report does not contain a list of the questions, but the fact that they were not understood would again seem to show that a question correctly asked is already half answered. For this reason our present Committee has prepared and suggests that a number of questions be submitted to the various operating companies, who would be requested to answer them for each of the basic diagrams presented here and for each voltage. These questions are presented here at present not for the purpose of obtaining answers, but first for the purpose of discussing the questions themselves.

The questions which we believe will in time bring out definitely the advantages and disadvantages of the various basic diagrams, if answered for various types of systems over a rather long period of time, are as follows:

1. How many circuits like this are there on your system?
2. How many of these circuits are single circuits, supplying load which cannot be supplied by any other circuit?
3. Type of structure?
4. Approximate total cost of all circuits installed, including structure?
5. Approximate total space (in cu. ft.) occupied by all circuits, including walkways (indoors from floor line to floor line)?
6. Type of disconnects (A & B) stick or gang operated?
7. Type of disconnect (C) sitck or gang operated?
8. Total number of interruptions on all circuits?

9. Total time of all outages on all circuits, including shut-downs for inspection and repair?
10. Total kwh's lost by all outages?
11. Total number of interruptions due to bus failures?
12. Total time of outages due to bus failures?
13. Total kwh's lost due to bus failures?
14. Total number of interruptions due to breaker failures?
15. Total time of outages due to breaker failures?
16. Total kwh's lost due to breaker failures?
17. How many times was switch (C) closed for breaker inspection?
18. How many times was switch (C) closed for breaker failure?
19. How many times was breaker operated for inspection only?
20. In how many cases of #19 was a defect found?
21. Number of troubles on circuit operating with (C) closed and breaker open?
22. Total kwh's lost through #21?
23. Number of times breaker failed to open under overload or short?
24. Total kwh's lost through #23?
25. How many times was #23 mechanical failure?
26. How many times was #23 relay failure?
27. How many times was #23 control circuit failure?
28. Total kwh's lost through #25?
29. Total kwh's lost through #26?
30. Total kwh's lost through #27?
31. How many hours did it take to find and clear #23?

Auxiliary Electrical Connections

NELA Publication #088 of April 1930 which is a report of the Electrical Apparatus Committee, entitled: "Electrically Driven Auxiliaries for Steam Generating Stations" is quite voluminous and is practically a text book on the subject. It contains records of auxiliary connections in most of the recent important steam plants and a very complete bibliography. As the title of the present paper implies we are now concerned with "connections," and not with apparatus, leaving the selection of motors, starters, and types of protective devices out of consideration. When we attempt to establish some basic principles to be followed in the connections of the auxiliary drives, we find that Publication #088 says too much and too little. It contains a great many complete diagrams - some good, some bad, and some very bad, some clear, and some complicated, and some having a multiplicity of supplies in one place and a bottleneck in the other. Even though there is a chapter on basic connections, it is not systematic enough nor complete enough for a comparative analysis.

An attempt is here being made to bring the auxiliary connections down to fundamentals in the form of some basic diagrams and subject these to a thorough discussion. Here it would seem that it is not so much a question as to which basic idea is preferable, as it is to decide when the one or the other is to be used, because each of them seems to have its field of application.

First of all we must remember that the auxiliary problem is an industrial problem with the definite requirement that the supply must never fail, that the auxiliaries must be like the captain on the bridge, the last thing on a system to kick out. It is obvious therefore that careful attention must be given to each switch and each connection to make sure that it is really needed, because if it is not needed it may become a source of trouble.

The next thing to remember is that as far as the power house operator is concerned, the auxiliaries are his most important load, his most important customer. An important customer generally gets a well designed substation, and so must each group of auxiliary motors have a well designed "auxiliary substation." It may not be amiss to again mention that the term "auxiliaries" is rather unfortunate, because it implies something which is of secondary importance and is treated as such by many station designers. It would be better to establish the term "station essentials" to take the place of the term "station auxiliaries."

The problem of connections can be subdivided as follows:

1. Sources of energy.
2. Connections in main energy supply station.
3. Feeders to auxiliary substations.
4. Connections in auxiliary motors.
5. Circuits to individual motors.

As far as the circuit arrangement is concerned, in No. 2, No. 3 as well as No. 4, there is nothing to be added to the foregoing discussion on basic main connection diagrams, except perhaps to mention that here is a good place to recommend two breakers per circuit (Figure 8) especially in the circuits coming in from the main sources of supply. The basic diagrams presented here do not show any breakers except in the case of a bus tie to indicate a definite condition, neither do they show any disconnects or bus duplications, all this being covered in the discussion on basic diagrams, so that the single buses shown here must not be taken as recommendations for single buses. In fact, it is hereby specifically recommended to have two sets of breakers in each power supply circuit, two sets of main buses, not less than two feeders to each auxiliary substation and two buses in each auxiliary substation, thus carrying the duplication through to the buses of the auxiliary substation, but stopping right there, because there would be no object in having two circuits to each motor, even though this has been done in a number of instances.

Basic Auxiliary Connection Diagrams

Figure 12

Figure 12 presents the oldest form of supply for station auxiliaries, a transformer from the main station bus, or a multiplicity of such transformers from the same bus, or a transformer from each station bus when

there are several buses in the station. To this can be added one or more house turbines either for heat balance purposes or for emergency.

Figure 13

Figure 13 is similar to Figure 12 except that it is for the case of a station having no buses at generator voltage, each generator stepping up to line voltage. The auxiliary transformers are therefore connected to the high voltage bus.

Figure 14

Figure 14 has an auxiliary transformer connected to each generator, each transformer supplying the auxiliaries of the particular unit and no connection between units. This is in accordance with the opinion prevailing today that future plants will be built as units, each unit having its own boiler, turbine, auxiliaries, and switching, each unit being considered a complete power house. When anything in the equipment is down, the particular unit with its boilers, transformers and line is down. Since such units do not even contemplate any steam header, there would be no object in connecting the auxiliaries of the various units on the same bus. This, of course, at once reduces the cost of switching enormously. Not only is the number of switches reduced to a minimum, but the short circuit rating is reduced.

Figure 15

Figure 15 is the same scheme as Figure 14 except that the transformers of the various units are connected together on the same auxiliary bus, requiring switches of much heavier rupturing capacity. It must be emphasized here that when the auxiliary system is, say, 2300 volts, each motor switch must have the rupturing capacity for the complete 2300 volt system.

Figures 16 and 17

Figures 16 and 17 show a shaft generator on each main unit instead of a transformer, requiring smaller breakers than the transformer scheme. Otherwise they are the same as Figures 14 and 15 respectively.

Figures 18 and 19

Figures 18 and 19 show tertiary windings on the main generator transformers; otherwise they too are identical with Figures 14 and 15 respectively. This scheme has been used in a number of cases, but has not been discussed a great deal. One difficulty that appears in this scheme is the necessity of knowing what the auxiliary load will be when specifying the main transformers and it is not always easy to obtain this information in time from the mechanical engineers. It would be well to obtain some operating experience data from those who used it.

Reserve Supply to Auxiliaries

Referring now to Figures 14, 16 and 18, some stations have arrangements whereby each generator normally supplies its own auxiliaries, but there is additional switching whereby in case of a transformer failure a supply is switched on from another unit. This appears quite simple, and it is comparatively simple when there are only two units, but with three or more units in a station it becomes extremely complicated to provide for a selective supply from any unit that may be operating at a particular time. In such cases it would seem preferable to connect all the transformers to a common bus (two sets of buses and two sets of breakers per circuit of course). It may be well to repeat here what has been said in the paper on basic diagrams about a second bus, because it is of such great importance to auxiliaries. There are cases of stations having duplicate, triplicate or even quadruplicate supplies and yet only one bus in an auxiliary substation that may be called upon to take care of the condensate of two large units. This is a vicious bottleneck that should be avoided and can be avoided at comparatively low cost. It may be well to emphasize here that as station auxiliary diagrams become more complex, it becomes more necessary and more difficult to watch on every step for bottlenecks, as they somehow sneak in here and there and are often overlooked. When one bottleneck sneaks into a connection diagram system, all the money spent on duplicate bus work, duplicate transformers or generator, duplicate switches and duplicate cable is practically wasted. Every existing installation should also be carefully checked up for bottlenecks; once they are found it should be easy to eliminate them without any great expense.

Quite frequently a small unit is provided to take care of emergency conditions, and is so dimensioned as to be able to pick up and carry the load of the essential auxiliaries only. Such a unit is either a "spinner" or a "pickup." The method of operation is shown in Figure 20. Two main buses are provided for the auxiliaries, the emergency unit being connected to one bus only and the main supply to the other bus only, and the bus tie normally closed. Two feeders, one from each main bus, run to each auxiliary substation, each connected there to a different auxiliary substation bus. In each auxiliary substation, the essential motors are normally connected to the bus which is tied in to the main bus of the emergency unit and the non-essential motors connected normally to the other bus. All that the automatic devices have to do in the case of a failure of the main supply is to kick out the one-and-only bus tie breaker. All the essential motors in all the auxiliary substations will automatically remain hanging on to the emergency unit and all non-essential motors will be out. Of course, each motor circuit in each auxiliary substation should have selector disconnects for transfer and test.

It would be well to discuss the suggestion that has been made in an article in the Electrical World of November 9, 1929, entitled "A Critical Analysis of Station Auxiliary Systems" to omit automatic switches from the individual motor circuits entirely and to provide one automatic switch for all the auxiliaries of a unit that have to operate as a group.

This question has not been subjected to sufficient discussion, even though at least one power house is said to use such a scheme.

Hydro-Plant Auxiliary Diagrams

In the study and discussion of auxiliaries, hydro plants have been left out of consideration as a rule, and yet there are hydro plants containing very elaborate switching installations for auxiliaries, the supply being either generator-transformers, shaft generators, or tertiary windings. The essential auxiliaries in a hydro plant do not represent a heavy load, the only essentials being perhaps oil pumps. The non-essentials, such as gates, air compressors, cranes, etc., are not operated continuously. It would seem a pity therefore to spend all that money on elaborate switching for hydro auxiliaries. It would be well to investigate the possibility of making all hydro auxiliaries d-c to be supplied from the exciters of the main units and to have a Diesel or gasoline engine for emergency and for starting up from a complete shut-down.

November 28, 1931.

DISCUSSION BY G. B. KERSEY (COMMONWEALTH EDISON COMPANY)

The author deserves much credit for his very clear presentation of the 11 bus diagrams and for his pithy criticism of each.

For more than 20 years the Commonwealth Edison Company has used as standard for all generating station 12 kv. switch houses, a diagram similar to Figure 10, except that the cost has been reduced by connecting 3 or 4 feeders to a feeder bus instead of only 2. This diagram has served the purpose very satisfactorily from all points of view.

However, about one year ago preliminary engineering was under way for a new 12 kv. distributing station. This station when fully developed will supply 80 - 12 kv. feeders receiving energy from our 66 kv. system through 5 - 100,000 kv-a. transformer banks. For this project 8 base diagrams were submitted for consideration in competition with the old standard. These schemes were very carefully analyzed and compared from the standpoint of:

(1) Reliability of supply with reference to the characteristics of the load to be served, with due consideration to the effect of outage at any point.

(2) Operating flexibility.

(3) Concentration of short circuit energy.

(4) Adaptability of bus protective schemes.

(5) Voltage regulation.

(6) Feasibility of extension for future requirements.

(7) Building space.

(8) Total Cost.

The old standard scheme would have required 142 - 3 pole breakers, whereas a diagram in accordance with Figure 2, which was finally adopted, requires only 116, at a corresponding reduction in estimated cost. We do not consider that in this particular application any items of engineering importance were sacrificed by the choice of the simplified diagram. The reduction in space requirements turned out to be an important advantage on account of space limitations of the site.

Some of the points which make a simplified arrangement more practical now than in the past, are:

(1) The adoption of a well designed isolated phase structure.

(2) Fully developed fault bus schemes.

(3) Adequate back-up relay protection.

(4) Multiplicity of circuits to substation groups which makes it possible to drop a group of lines without impairing service to the substation supply.

In a design of future distributing stations, we may be able to justify a still further simplification of bus diagrams by the omission of feeder breakers, relying entirely on the bus section breakers for automatic operation and for isolating equipment as required in maintenance work.

Installation of a large amount of equipment for flexibility purposes should be carefully considered. If the flexibility is provided for the purpose of permitting greater utilization of more efficient equipment, it may be economically sound. However, if the extra equipment is put in largely to make operation and maintenance a little more convenient, it may be an expensive luxury. The Commonwealth Edison Company has an extensive 66 kv. system interconnected to various generating stations. The switching centers have been worked up on the basis of Figure 5. Although diagram 8 was considered highly desirable, the difference in cost between Diagram 5 and Diagram 8 has been estimated at $1,000,000, which figure is probably far beyond its actual value.

Auxiliary Power

In considering a basic diagram for an auxiliary power supply, one of the principal considerations should be the segregation of essential motors on a strictly unit basis, i.e. the failure of the auxiliary power supply at any one point should affect not more than one generating unit. In one of our generating stations, two of our older generating units are relied upon to supply a rather important street railway load. A rehabilitation of the auxiliary power supply to these units was considered necessary and the cost estimated at $25,000. A study of the base diagram revealed that fundamental changes could be accomplished with very little change in equipment and at a cost of only $4,000, with very satisfactory results in reliability of service. That is to say we found it expedient to change the diagram rather than to modernize the equipment.

In the layout for auxiliary power supply to the first units at Crawford Avenue Station, considerable duplication of equipment was provided for the reason that continuity of operation of those particular units was vital to the system at that time; we tried to reduce to a minimum the possible outage of generating units due to weakness in auxiliary power supply. Later units in the same station, even though much larger in capacity, were not treated so generously. We felt justified in taking advantage of the the fact that with the growth of the system and increase in system reserve, that the continued operation of any individual unit is not so important.

DISCUSSION BY R. E. GREENE (DETROIT EDISON COMPANY)

I agree wholeheartedly in what I believe Mr. Samuels is trying to accomplish. I suspect that he is not particularly concerned in obtaining say 5 standard diagrams. Instead, I believe that he is emphasizing that no station diagram should be accepted, until the engineer has convinced himself that every piece of bus, every oil switch and every disconnect performs a useful purpose and is economically justified. Such scrutiny will reduce the number of complex diagrams.

We in Detroit could not find much fault with Mr. Samuels' preachings. Our station diagrams are certainly simple and we sometimes wonder at the seemingly complex diagrams used by others. We recognize, however, that we should be careful in criticizing the work of others because we don't know their local conditions. Mr. Samuels does not show much enthusiasm for diagram with by-pass in Figure 3, and neither would we in Detroit. However, I can well imagine that John Jones up in Maine might find this diagram perfectly proper for some cases.

Mr. Samuels indicates on the first page of his paper that station and system diagrams should be coordinated. I think that more emphasis should be placed on this fact because system connections and conditions do materially influence the choice of station diagrams. I will cite two such cases on the Detroit system. The large switching stations of our 24 kv. cable system have a number of bus sections connected through reactors to a synchronizing bus. The cable feeds to the distribution stations are spread over the bus sections, with not more than one per bus section. We must be able to lose at least one cable to any substation and we must be able to withstand the loss of a generator. Hence the dropping of a bus section simply means that we have dropped spare generating and spare cable capacity. We use single bus construction and it is entirely satisfactory because of our system connections. The second case concerns our distribution stations in residential areas. Here we distribute through an ungrounded 4800 volt system. Carefully insulated and protected single buses are used and we have never experienced a bus failure. We believe that this lack of trouble is due at least in part to the fact that the system is ungrounded. You will note that in these two cases system connections and conditions have caused us to choose diagrams contrary to the practices advocated by Mr. Samuels. He believes in two sets of buses for all well designed substations.

The paper states that the diagram shown in Figure 1 should be used only when not another cent is available under any circumstances. This diagram has no disconnect for line side of breaker. I think this statement is a little strong as we have plenty of radial 4800 volt circuits from our suburban substations in which the line disconnect is omitted because it is unnecessary.

It seems to me that the questionnaire proposed asks for so much data that it will defeat its purpose. The longer the questionnaire the less satisfactory will be the results. I believe that data should be collected

on the use of and operating experience with the various diagrams, but questions concerning costs and kw-hr. lost should be omitted. Such questions are important, but I think they are affected too much by local conditions to be used in a general questionnaire. The real object of the questionnaire is to show how the industry as a whole handles each case so that an engineer will make sure that local conditions justify a complex diagram before he chooses it.

The paper points out that accepted standard diagrams should apply to metal clad and other switchgear. I believe that the Committee, for the present at least, should consider diagrams by themselves and that the influence of types of switchgear should be considered later.

DISCUSSION BY PHILIP SPORN (AMERICAN GAS & ELECTRIC COMPANY)

The report prepared by Mr. Samuels is certainly presented in such a way as to provoke discussion. It bristles with statements that are sure to be challenged and in some cases condemned. I am rather suspicious that in making some of these statements the author held his tongue in his cheek and smiled at the thought of the reaction his crisp conclusions would produce on those in close touch with this type of work.

The plea for simplicity is based on the following three statements contained in the report:

I - Breakers are much more reliable than they were in the past.

II - There are very few loads left that are supplied by one circuit only, so that it should be possible to take any circuit out of service for inspection or repair without jeopardizing service.

III - When there is only one supply circuit, it is necessary to be prepared for shut-downs from line troubles which will be more frequent than breaker troubles. And if the circuit can stand such shut-downs from line troubles, it should also be able to stand the infrequent shut-downs of short duration for breaker inspection or repair.

Discussing these in order:

(1) Everyone will agree that breaker blow-ups are not so frequent as they were in the past. But who can say that we do not have breaker troubles? Or that the breaker situation has reached such a degree of

refinement that its reliability ceases to be a problem? In any case breakers must and do have routine inspection 3 or 4 times a year, and at least one inspection a year that is very thorough. A complete inspection may mean that the breaker is out of service for a day or even longer. Obviously very few loads can be interrupted for this length of time. The prompt clearing of trouble on any feeder depends on the proper action of the circuit breaker, and the breaker cannot be expected to function properly indefinitely unless it is adequately maintained.

Constant improvements are being made in breaker design. Last year we changed to the non-metallic type explosion chamber on practically all breakers of 130 kv. rating of that type. This meant having each breaker out of service for a considerable length of time. More recently we have incorporated the "De-ion" or "Oil blast" principle in many existing breakers, and expect to do the same to a great many more. While it is believed that these breakers are reliable, nevertheless we expect to have certain operating difficulties and expect that certain defects will be found by experience. By the time these are proved reliable, new ideas of breaker design will be formulated, and the whole process will be repeated. Thus, it does not appear that the final solution has been found for breaker design, nor that it will be reached during the next decade or during the succeeding one. The crisp statement that breakers are now more reliable than they were in the past therefore does not adequately cover that broad question.

(II) If Mr. Samuels cares to go with me, I will be glad to show him on the property of the Atlantic City Electric Company in New Jersey; The Scranton Electric Company in Pennsylvania; The Wheeling Electric Company in West Virginia; or the other subsidiary companies in Ohio, Indiana, Michigan, West Virginia, Virginia, or Tennessee, that a large amount of the revenue is obtained from customers fed by one circuit only. In most of these cases it is not possible to take the circuit out without jeopardizing service. Furthermore, means must be provided for proper maintenance of all equipment pertaining to the feeders.

(III) As to being prepared for shut-downs from line troubles in cases where there is only one supply circuit, I cannot agree. We now work circuits at all voltages hot, with a great degree of success. On the other hand, no means has been found of inspecting or repairing a breaker while it is energized. Some may have tried it but they did not live to tell about it. Some means must, therefore, be provided for breaker inspection so that service will not be interrupted. It must be remembered that perhaps 9 out of 10 cases of line trouble mean that the circuit is out only a matter of seconds. It is a rare case when a cyclone picks up a line and lays it down in the adjoining county; in such cases the customer would probably not need service for some little time.

Furthermore, we expect in the future to do even less in the way of duplicate lines for important service, than we have in the past. We have gone so far as to propose to the manufacturers a breaker that will open the circuit and reclose in a matter of ten cycles. Single circuit feeders

with such a breaker should practically insure the equivalent of continuous service to the customer. Operating troubles with such breakers when we get them are bound to exist for long periods after their initial development, and some scheme is necessary to insure proper maintenance and at the same time without interrupting service. But the overall cost should be a great deal less than building a second circuit, one that is normally dead or very lightly loaded, excepting in extreme or abnormal conditions.

There have been too many designs made in the past by consulting engineers that looked good on paper, but that did not work out in practice. Too frequently the designer of such schemes has not followed them through to acquaint himself with actual operating results. If he had inspected these at some later date, it is quite likely that he would have found that the scheme had been revamped in order to be operative. But that does not hold for all designs. A great many are based on solid and properly integrated operating experience; we ought to be careful in making, therefore, general and broad sweeping criticisms of switching layouts.

Two theses are stated in the report to serve as a guide for the discussion of basic main connection diagrams; one states that there should be a tendency to make the basic diagrams of all circuits of a station and even of a system identically the same; the second states that any device or connection provided for use in emergency only should be so simple that any operator will have to do no thinking or planning in order to use it. Referring to the first thesis, I believe experience shows that it is impossible to attempt to standardize a set of schemes and apply them universally over a system or a group of systems. Rationalization and not standardization should be the goal. The insulation problem serves as an excellent example. During the past few years we have done a lot of work in attempting to standardize insulation. It has been definitely shown that it is impossible to draw up a set of standards to cover all cases. Local conditions enter the picture to such extent that we may standardize for a certain locality but conditions may be so entirely different in a locality perhaps only ten miles distant that the same standards will not apply. The same is true with switching schemes, that is, certain fundamentals may be outlined but cannot be applied to all cases. The plan for serving, let us say the Empire State Building, will be very different from the layout for a rural feeder. The one represents a great concentration of power while the other represents a small load with an exceptionally low rate of return on the capital invested. Again, loads in the same area may have totally different characteristics and hence call for a scheme of very different complexity.

The second thesis dealing with additions or connections for emergency use is deserving of some comment. As a power system expands and becomes increasingly complex, we must realize the need for operators of a higher calibre. This is inevitable and is the price we pay for system growth. In many cases today we will probably find that the operators have a better grasp of the situation than did the engineers themselves some years back. Thus, if a system calls for a scheme that may at first sight seem to be somewhat complex, we need not fear for it from the standpoint of the

operator. The important question is what scheme is necessary to adequately solve the problem. It is obvious that it should be as simple as possible and as is consistent with the operating needs.

Basic Main Connection Diagrams

Referring to the eleven basic diagrams, I am not sure that they are actually basic. There is no fundamental difference in Figures 1, 2 and 3. They each consist of a bus and a breaker. I do not think that Figure 3 should be condemned for there may be cases where by-passing the breaker with a disconnect is warranted.

Figure 7 is probably not used to any extent and is certainly not a basic diagram; however, Figure 6, which is really a main bus and combined reserve and transfer bus, is a fundamentally sound scheme, for it allows the substitution of the transfer breaker for any breaker on the incoming or outgoing circuits. As previously stated, we have rebuilt a great many breakers during the past few years. In such cases a breaker would be out of service for several days. The transfer arrangement made it possible to keep the circuit in service during this period, and with the proper automatic protection. During the coming year we expect to apply the oil-blast feature to the existing breakers on the seven 132 kv. circuits out of the Philo Station. The transfer bus and breaker will again allow the work to be carried out without interfering with normal operation. After these changes are made, there will undoubtedly be cases from time to time outside of routine tests where the transfer feature wil be advantageous. Furthermore, there will be future developments in circuit breaker design that will call for further changes in existing breakers.

I agree that it is difficult to justify the double breaker arrangement shown in Figure 8, - this is especially true for voltages in excess of 66,000.

Our early tendencies in system design were always in the direction of a single bus and a single breaker. This was partly due to lack of operating experience and partly to the fact that funds were not available for more elaborate schemes. We found, however, by bitter experience that these facilities were not always adequate and soon realized that in a great many cases, the cheapest arrangement in the long run was proper by-passing facilities.

I am sorry I did not receive Mr. Samuels' paper in time to permit a thorough discussion of the fundamentals of switching, but a fairly complete discussion is included in pages 5-19 of a paper prepared for the International Conference on Large Electric High-Tension Systems (copy of which I am attaching), and I should like these pages to be considered as a discussion of the points with regard to switching fundamentals raised by Mr. Samuels.

While this paper was written more than a year ago, it represents our views on this entire matter at present, with one exception. This deals with the question of maintaining a reserve bus at all times under normal conditions, a point discussed on page 7, paragraph 2, of the paper. While maintaining a reserve bus is important, I believe that if there are duplicate sources of feed to the given load area, then the two buses may be connected together through a sectionalizing breaker and both normally kept energized, provided the duplicate circuits are distributed on each bus and provided proper differential or ground fault relaying is used to insure that the clearing of one section of the bus will not interfere with the other.

In summarizing, I would like to stress one paragraph from the paper just mentioned; this deals with the question of rationalization of switching.

"At this point it may be well to sum up the principles of rationalization that have been brought out. First of all, the designer has at hand certain fundamental parts that make up any switching arrangement, that is, he has the various types and combinations of buses that have been mentioned and this, along with a knowledge of present conditions to be met and a fairly accurate knowledge of future conditions, should make it possible for him to arrive at a switching scheme that is comparatively simple, economical and one that still gives the necessary reliability. That is, he will use only such of these elements as he can economically justify in each particular case; he will always use each element to perform a given function under all conditions; he will combine functions where possible and separate his functions where reliability can economically be given the necessary weight. Finally he will let economic considerations determine the extent of his call upon the various elements in the combination that he finally evolves as this switching arrangement."

Mr. Samuels is, of course, on sound ground when he suggests that actual operating experience be used as the basis of designs. I have tried to convey the idea that a good many operating arrangements now being used have been evolved on the basis of actual operating experience. In discussing this questionnaire sent out by the Edison Association (and it was a very frank questionnaire calling for some very frank answers), we found that we did not in many cases get what were considered the real reasons behind the switching arrangements. It was for this reason that we had to go back to some of the companies for further information, but some of the answers that we did get threw a great deal of light upon the basic considerations that determine the switching arrangements and I believe that when the work is completed we are going to get something very real in the way of operating experiences to be used for the purpose of establishing a set of principles to be followed in switching.

A set of 31 questions is proposed in the report under discussion and it is suggested that, if answered, it will definitely bring out the advantages and disadvantages of the various basic diagrams. I notice

that out of the 31 questions, eight deal with the question of total K.W.H. lost as a result of outages, but who ever heard of K.W.H. lost as a sale as having any bearing on the question of whether or not we need adequate facilities, by-pass facilities, etc.? If this were all that was worrying the power supplier, there is no question that the electric system could not justify anything more than single boilers, single generators, single buses, single lines, and so on down the line.

But what is loss of energy sale to a customer, let us say, who has a glass mill and uses a battery of 30 motors to cool his glass tank? The monthly bill of this customer is say $2500.00, but every time he has an outage where power is not restored within two minutes, he loses the bottom of his tank at a net cost of $7000.00. Does anybody imagine that energy that might not be sold within a period of an hour is the real crux of problem in a case like that? Or consider the case of a high pressure ammonia plant, using 1400 atmosphere compressors, where the loss of voltage <u>for a period longer than two seconds</u> means a stoppage of 4000 H.P. compressors and the tying up of the plant in so many knots that it takes half a day to get it started again, what does energy loss mean here?

A properly put question may be half the answer, but we certainly have got to be careful what kind of question we put. I do not want to believe that the inadequacy of a great many of the other questions is due to a lack of familiarity with actual operating conditions. If they were put in for the purpose of arousing discussion then the object was most certainly achieved. Consider, for example, question 14 as typical. This question asks the total number of interruptions due to breaker failures. I remember one case on one of the properties of the American Gas and Electric Company where for a period of two years we knew that certain breakers were inadequate. Covers were being blown off almost every time a short circuit had to be interrupted and much worse failures would have occurred if the practice at that time hadn't been to open the breaker and thoroughly overhaul it and tune it up every time it opened a heavy short circuit. The breaker simply was not permitted to blow up in this case, and the fact that we did not have any actual blow ups didn't mean that we did not need by-passing facilities which made such frequent inspection at that time possible.

We have made a start on this subject of switching in the A.E.I.C. Committee on Switching and Switch Gear and we expect that the work will be continued. I am sure that the fact that our NELA Committee has taken up the work will help the cause along. It is possible that the cause can be furthered by cooperation with regard to some of the work of the two committees, or even by consolidation, but I believe a great deal more of thinking and hard work is necessary before questionnaires can be sent out to serve as a basis for the establishment of principles or standardization. And above all, we want to go very easy on standardization.

DISCUSSION BY H. B. WOOD (STONE AND WEBSTER ENG. CORP.)

It may be said that the extreme limits of switching for a circuit are from one having a single circuit breaker with a disconnect on the bus side to one having three breakers, two of which are for selecting one of two buses and a third for the normal automatic breaker which is backed up by one of the other two. The first represents the least expensive and simplest circuit. The latter represents one giving great flexibility but involves a maximum expenditure that in most cases and possibly in no case can be warranted today. Somewhere between these two arrangements, is the one that best fits a specific condition.

In general, the simplest arrangement is the least expensive and the safest but it may not fulfill all the conditions for service. Where the system set-up is such that any circuit may be taken out of service without interruptions to customers, duplicate circuit breakers are not warranted. However, there are still many customers fed by a single circuit. If this is an overhead circuit, which is subject to only momentary interruptions, there may be no serious complaint from or hardship to customers. However, to shut down such a circuit long enough to overhaul an oil circuit breaker would be out of the question and some means should be provided for maintaining the breaker. In a simple outdoor substation a transfer air break switch to a transfer bus could be provided at small cost, this bus to be supplied through a circuit breaker in the form of a bus tie breaker or a duplicate breaker from the supply source. On indoor work, however, there is always a hazard when load is transferred by means of disconnecting switches, as the load may be interrupted through the disconnecting switches with consequential troubles. It is possible to guard against this to some degree by interlocking which, however, adds complications and is not always infallible.

On stations of prime importance where there are a number of important outgoing circuits, it is advisable to have some way of clearing a fault in case a circuit breaker should fail to function. This may be done by means of a group bus which is connected to the main bus through a circuit breaker, this breaker acting as the backup for each breaker of the group, or it may be done through bus sectionalizing breakers.

Figures Nos. 2, 4, 5, 8 and 10 would seem to include a sufficient variety of connection diagrams for all except very special cases. Diagram No. 33 is suggested as one that is economical and not complicated.

In this diagram the tie disconnect is left normally open and the two circuits are operated independently but during maintenance the two circuits are fed from one breaker. It is believed that this connection has most of the advantages of Figure 9 and is less expensive.

In reference to providing a connection bar in place of a disconnect, as mentioned in the second paragraph of Page 4, this, in general, would not be satisfactory as it may require, to permit removal of the bar, grounding the side of a circuit that it is desirable to keep alive.

The diagrams do not show a grounding or test switch. As this is part of the switching of a line, we believe it should be shown, especially if these diagrams are to be used for standardizing on metal-clad equipment. All line circuits over 6600 volts at power stations or main substations should have provision for grounding or testing disconnecting switches.

It hardly seems logical to use a simple switching scheme requiring only one breaker for each main circuit and complicated switching for station service. If the system were so set up that it can lose any one generating unit, then it is possible that it can lose any one of the auxiliaries of this unit. It costs less to relay an auxiliary than it does to relay a main unit, but it is possible that the auxiliaries may be sufficiently reliable to make duplication of switching unnecessary. Where duplication appears warranted, double supply need not be through double breakers but may be secured by a properly sectionalized bus with each section having a source of supply.

It is stated on page 12 that Figures 16 and 17 require a smaller interrupting capacity oil circuit breaker than the schemes having a transformer. We believe in general that this is not correct since in many cases the shaft generator is relayed by a transformer which determines the interrupting capacity of the breaker.

The use of exciters for station service should be discouraged. In addition to the risk to the continuity of generation, most modern exciters are of the quick response type controlled by automatic voltage regulators which may produce too great a voltage on auxiliaries, especially those requiring operating coils.

Figures 1 to 11, inclusive, apply to individual circuits; Figures 12 to 20 to station composite diagrams. We believe that at the present time discussion should be limited to individual circuit diagrams, keeping in mind, of course, their application to the system.

DISCUSSION BY R. T. HENRY (BUFFALO, NIAGARA AND EASTERN POWER CORP.)

We fully agree with Mr. Samuels as to the need of getting down to basic principles in the choice of diagrams for various generating stations and substations and that recent improvements in apparatus available has greatly changed the situation, but we do not fully agree wih Mr. Samuels in some of his criticisms of some of the diagrams shown in his paper.

While Mr. Samuels seems to have no use whatever for the "by-pass" as shown in Figure 3, we feel that the "by-pass" still has, and probably always will have, a place in some stations. There are many cases

where a second breaker, or a second way of feeding a circuit, is out of the question. It probably is true that such circuits go out of their own volition often enough but that is something which cannot be avoided. On the other hand, deliberately taking a circuit out of service when it could be avoided is coming to be the unpardonable sin in the electrical industry. The fact that a scheme does not readily lend itself to metal-clad construction should not be considered too seriously.

As to the transfer bus scheme shown in Figure 4, whether it originated on trolley switchboards or not, we believe that this diagram is, without exception, the simplest and most efficient diagram there is for providing continuous service on each of the outgoing circuits without unnecessary duplication of equipment. The same diagram, without the bus-tie switch, is also a very simple and efficient diagram with very real merit.

As to the double bus, single breaker scheme shown in Figure 5, this scheme has so little advantage over the single bus single breaker arrangement that it is very doubtful if there are many cases where it could be justified. The likelihood of a failure of a bus is certainly very much less than the likelihood of a failure of a circuit breaker.

The so-called "asylum diagram" shown in Figure 7 is probably not justified in many cases though it has merit where a station is operated in two sections. As to the possibilities of errors, this diagram looks very much simpler if the bus selectors are placed near the buses and the three breaker disconnects are placed near the breaker. We have succeeded in arranging the equipment using this diagram in such a way that there is practically no danger whatever of confusion or opening the wrong disconnect.

Figure 8 surely is the "aristocrat" of basic diagrams. It is the diagram that has been used more than any other at Niagara Falls where the number of circuits is not so great, but where each circuit is of considerable capacity and where the need for absolute continuity is very great. Another diagram that has been quite popular and very successful at Niagara Falls, is a combination of Figure 8 for incoming circuits and Figure 4, without the bus-tie breaker, for outgoing feeders. In these cases the second breaker on the incoming circuit is generally made large enough to carry all of the outgoing circuits in the corresponding section, making it possible to clear the main bus without any interruptions. This scheme requires only one extra breaker for each group of circuits.

Figures 9, 10 and 11 represent rather special cases and probably will not be very generally used.

As to auxiliary connections in generating stations, we fully agree with Mr. Samuels that there is a great deal of room for improvement. There are many cases where excessive duplication and complications are provided in some parts with very serious "bottle necks" in other parts. It is probably true that the need for absolute continuity is as great, or greater in connection with some of the station auxiliaries than for any other

service, but this need can best be met by a reasonably simple arrangement with plenty of duplication but without some of the extreme provisions which have been made in some cases.

Altogether, it should be very helpful to have attention centered on the basic principles involved in the choice of the diagrams for various applications.

DISCUSSION BY D. M. JONES (GENERAL ELECTRIC CO.)

A review of Mr. Samuels' interesting paper did, as I believe was intended, suggest certain viewpoints which seemed to justify exposition.

After listening, however, to the several very able discussions of this paper that have already been given, I find that most of the things that I had desired to say have been very competently set forth and my purpose in speaking will therefore largely be that of emphasizing certain phases of this question which seem to warrant such a procedure. In doing this, I recognize that I will be of necessity restating to some degree what has already been well said and crave your indulgence to that extent.

The Fundamental Basis of Substation Design

In opening the activity of the Subject-Committee on Substation Design Fundamentals with this paper, I have inferred that it was the intent of this article to discuss the fundamentals of station design even though its actual title does not entirely support the inference.

On this basis I will take the liberty of at least directing my comments at the general problem of Station Design Fundamentals and suggest for your consideration that there is but one such fundamental basis, which I will attempt to define as follows:

> A sub- or generating-station should contain such equipment and facilities as will render a sufficient service to justify their existence.

In attempting to put this principle into practice, the real problem of course becomes that of evaluating the service which will be rendered by each component part. As a major aid in handling this phase of the situation, I would suggest a complete realization of the fact that a substation is not a disassociated entity but rather one of the many units that go to make up that complex organism known as a "power system." This in turn immediately indicates that the next stone in the basic structure of substation

design should be a competent conception of the make-up of that organism of which the unit is to be a part.

The make-up of the organism as thus used is intended in its very broadest sense and is therefore considered to range from the type and arrangement of physical equipment, the financial and political background, the policies of the management, the relative competence of the personnel, to the class of service desired by patrons and the class of service rendered. In other words, both the whole complex structure of the power system and its full background will have their direct influence on the return which will be obtained from the various items which may be included in the station design.

From this viewpoint, it is evident that typical one-line diagrams of bus, disconnect and oil circuit breaker arrangements are but remotely associated with the fundamentals of station design. In fact one-line diagrams would appear to be more nearly the pictorial records of certain engineering conclusions which have been arrived at in the process of developing a logical station design in any particular case and thus normally should appear well toward the end of the period of that engineering activity.

From this standpoint, it would seem to be particularly futile to try to rate types of diagrams on their intrinsic merits, disassociated from any background. In fact both the development and present status of power systems seems to plainly indicate that there is more than one basic connection arrangement which can be successfully used in producing a satisfactory power system. It is also true that, once a system has been developed to the present status on any one of these workable connection arrangements, it will often be much more justifiable to continue with the types of layout that are logically dictated by the system scheme than to change to other layouts even though they might be considered somewhat better under many conditions. All of which simply again emphasizes the intimate relationship between the system and its parts.

Money Available and Substation Design

In the detailed discussion of the various connections in the paper it is suggested that a certain arrangement could be justified only on the basis that there was not another dollar available. This comment seems to me to again suggest a return to fundamentals but this time to the fundamentals of power system organization, and in this light I would propose the conception as basic in such an organization that the engineer should plan to use all the money on which he can show a satisfactory return. This suggests that the "money available" is always a relative, never an absolute quantity.

Simplicity vs. Complexity in the Light of Fundamentals

In the general discussion of the different connection possibilities, it seems to me that there is a suggestion that in returning to

fundamentals we would logically find ourselves also turning from complexity to simplicity in station layout.

In this connection, I would like to suggest that we do return to the fundamental conceptions just outlined, and consider that, just as a substation is one of the elements that goes into the larger organism called the power system, so is the power system one of the elements that is being incorporated into the still larger organism, our modern civilization. Furthermore, just as the layout of the power system will in a major way dictate the layout of the station, so will the make-up of modern civilization dictate the ultimate layout of our power systems and through them in turn our substations. Next I would propose the realization that the steady march of our whole modern civilization is definitely in the direction of increasing complexity. From this standpoint it would seem that there is little hope of finding our past trend in substation design suddenly back-tracking in the direction of simplicity through the procedure of returning to fundamentals. We are evidently definitely on the road to increasing complexity in all phases of our activity. The thing that is indicated by a return to fundamentals is simply that our progress in the direction of complexity should be an intelligent progress and that each additional increment of complexity should be carefully scrutinized to see that it affords sufficient additional benefits to justify its acceptance.

Standardization and Design Fundamentals

Now, in conclusion, let us return once more to first principles and consider in that light the old question of standardization, as it is unavoidably associated with substation design as well as in some way with almost any other activity in which we may be interested.

It is at once evident that, being a method only, standardization can never be an end in itself, and the degree to which it is applied should therefore always be determined on the basis of the net returns obtainable from it.

In setting up the balance sheet of returns, good and bad, which may be attained through the use of this method, it is of course evident that an increase in the standardization tends in general to reduce first costs but at the same time to stifle change and therefore development; while a decrease in standardization operates to stimulate variation and therefore progress but at the expense of an increase in costs.

The problem is therefore one of determining with the most far-seeing judgment the optimum degree of standardization in terms of net benefits receivable. This I assume is what has just been referred to in the discussions as the "rationalization of standardization."

This viewpoint logically interpreted will afford little consolation either to one who would advocate a maximum standardization either as a fetish or in order to avoid the responsibility of making recurrent decisions; or to one who would sponsor excessive diversity either as a means

of expressing an individual consciousness or as an agency for personal advertisement.

The proper degree of standardization will in each case thus be a difficult question as the bases on which judgment should be rendered will be multitudinous and complex. It should, however, be of considerable help in this endeavor to keep in mind a clear basic picture of the problem.

It may be justifiable in closing to mention the fact that the whole electrical industry has grown in a very few years from nothing to its present enviable status and that necessarily in a period of such rapid pioneering development variation has been in the ascendency. This industry is now, however, an existing fact and the next phase of its growth may conceivably be one of consolidation and therefore logically involve an emphasis on economics. In the light of this background, it would not be surprising if substation design practice along with other procedures were at this writing on the diversity side of the optimum amount of standardization and that the coming phase will evidence an increasing desire to more fully attain the optimum itself.

This can be and should be only a suggestion on my part as the ultimate decision as to the proper amount of standardization lies with those who are directly responsible for power system construction and performance.

DISCUSSION BY J. B. ADAMS (ALLIS-CHALMERS MFG. CO.)

This is not a critical analysis of the virtues of the various basic one line diagrams in our generating and substations. It is rather a statement of what is now in service in metal-clad switchgear of Allis-Chalmers Reyrolle design showing what is available for the man responsible for the basic one line diagram so he can more easily work out his own special requirements.

As long as we have different ideas of the relative importance of such basic features as flexibility, continuity, convenience, and simplicity, we will also have variations from the optimum simple circuit.

The elimination of complicated switching arrangements is desirable and certainly justified by economical considerations. How much greater is this simplification justified by safety considerations!

In the modern metal-clad installation there is no place for a single open disconnect no matter what the special requirements may be; in fact, a single exposed live part at any point may be considered as defeating

the basic idea of the installation - absolute safety.

As affecting our older ideas of reliability, metal-clad gear is exerting a profound influence. With bus insulation which includes an enormous factor of safety, completely enclosed, there is no longer the same reason for a reserve bus from a reliability standpoint. Breakers are now more reliable which is the basis of using a single breaker where two were formerly used. Buses are now much more reliable and this should be the basis for eliminating the reserve bus. The only sound excuse for the double bus is where special considerations of flexibility or division of load exist.

In the following diagrams we have, for its possible suggested value, departed from the standardized diagram symbols in two particulars. We have shown the movable portion of a switchgear unit at the side conforming more nearly to the actual construction and drawout arrangement. And, we have shown the disconnects as plugs and sockets instead of arrow heads.

Metal-Clad Switchgear One Line Diagrams

21 - Is the usual single bus single breaker unit. The CTs may be located on the feeder side or in the movable portion or in both.

22 - Is the same as number twenty-one with the addition of oil immersed by-pass. When the by-pass is closed and the breaker open or withdrawn, overload protection to the feeder is assumed by a back-up breaker feeding the bus. The by-pass is, of course, interlocked with the feeder breaker.

23 - Is a bus sectionalizing breaker.

24 - Is a removable oil-immersed bus totalizing CT unit.

25 - Is a removable isolating and/or grounding unit used wherever a disconnect is needed for any special purpose. This avoids the use of any open disconnects in connection with any metal-clad installation. It is, of course, interlocked with its energizing breaker.

26 - Is a safe and convenient method of grounding the feeder. With the breaker in the racked out disconnect position, one side is grounded by flexible ground. Extension plugs are placed on the other side of the breaker. The breaker is then racked in, the extension plugs connected to the feeder. The breaker is then closed which grounds the feeder through the breaker, the only safe way to ground any feeder.

27 - Is the usual main and reserve bus, single breaker, with oil immersed selector switch interlocked with the breaker. Continuity of service on the feeder is maintained during transfer

28 - Is a cheaper arrangement of selector, the connecting plugs being transferred by hand for the other bus orifices. Several minutes interruption

to the feeder service is necessary when this changeover to the other bus is made.

29 - Is the usual main and transfer bus layout with oil-immersed transfer switch connecting the feeder to transfer bus. Interlocked, of course.

30 - Is the bus tie unit necessary for energizing the transfer bus of number twenty-nine.

31 - Is the regular double bus double breaker arrangement requiring two metal-clad units.

32 - Is a metal-clad transfer unit for transferring a feeder from its voltage regulator to a transfer bus, maintaining uninterrupted service on the feeder and at the same time killing the regulator for work. A three-pole visible plug switch is sometimes added as an extra visible safety feature.

DISCUSSION BY H. E. RUGGLES (WESTINGHOUSE ELECT. AND MFG. CO.)

We are naturally very much interested in Mr. Samuels' proposed analysis of generating station and substation connections with the idea of determining fundamental arrangements which may govern station cost. The program outlined is comprehensive and will require a great deal of study if reliable conclusions are to be reached. We, therefore, refrain from specific comments since the four or five days available following the receipt of the paper has not permitted a proper study by our engineers concerned with such problems. However, we do wish to state that such an investigation and study is very desirable. The almost endless variety of connection arrangements in stations handicaps the manufacture to a considerable extent and tends to increase the cost of such an equipment and the time required for delivery. This is particularly true as related to the newer types of metal-clad switchgear. A recognition of certain fundamental and economical arrangements by operating companies should prove beneficial to the elimination of connection schemes involving specialized apparatus construction.

The selection of a connection scheme for a new station or a new system may be difficult enough, but the revamping of switching arrangements in an old system or station to provide for increased capacity and loading usually results in compromises and connection arrangements that are not all that could be desired.

A thorough consideration of the problems presented by Mr. Samuels' paper should develop information of great value both to operating companies and manufacturers of switching equipment.

DISCUSSION BY L. M. SMITH (ALABAMA POWER CO.)

Mr. Samuels' statement that there are few loads left which are supplied by one circuit is too broad and is not borne out by facts.

Mr. Samuels' comment that maintenance can be done on short duration and that any circuit can be taken out of service now and then is not correct. Few lines of any importance whatsoever can be taken out of service for anything except emergencies. In fact, lines are now being built as near trouble proof as practicable and with instantaneous reclosing breakers at the source.

Mr. Samuels says that a disconnecting switch is only a necessary evil. In the application of switches, a number of things must be considered, not the least of which is the safety of the men who operate them and the amount of time that would be lost with any other device. Many companies are getting away from the hook stick type of switch and are installing only group operated switches which are under orders of the load dispatchers. Some few accidents may have happened from improper operation of switches, but it is almost certain that many more accidents would have happened had some less expensive means of opening the circuit been provided. Mr. Samuels' idea that an operator should not have to plan his movements in a station or think about what he is doing is quite foreign to our ideas of what constitutes a good operator. We believe that the safest man around electrical equipment is the one who does think and plan his movements.

In specific cases, all companies at one time or another may have installed unnecessary switches and thus complicated the layout and increased the cost of the installation. On the other hand, there are many times when the cost of the switch is a negligible part of the total cost of the station, and when safety and continuous service are at a premium we believe the expense warranted.

It is unfortunate that Mr. Samuels was not able to attend the Atlanta meeting and hear the discussions which his paper provoked. I beleive he would have had a lot of fun, and I know that if his paper makes us think about the switching schemes which occur to us and if it makes us give a little more thought to justifying every piece of equipment which is up for consideration, both his paper and the discussion will have been worth while.

DISCUSSION BY M. M. SAMUELS (BY LETTER)

There is another diagram which should be discussed even though I am not ready to call it basic, and therefore did not include it in the list of basic diagrams. It is No. 34. The reason I don't consider it basic is

that it is only good for one definite condition. The idea is that normally breakers B and D are open, generator No. 1 feeding into transformer #1 and generator #2 feeding into transformer #2. Only when generator #1 is disabled and at the same time transformer #2 is likewise disabled, disconnect E and breaker C are opened and breakers B and D are closed, thus feeding from generator #2 into transformer #1. I never heard of anything like this happening, but it may have happened. If the alarm clock in the operator's bed room happened to ring at the same time and gave the alarm, I would call it a real coincidence. The scheme involves a rather heavy duty expensive switching and bus system and it is difficult to see the need for such an investment. For such an extreme "coincidence" which certainly falls into the field of unexpected accidents, it would be better to depend on dragging a set of cables to make the cross connections. However, this diagram seems to have the additional advantage of always having two breakers in series, similar to Figure 10, and it would therefore be interesting to have the opinion of those who have had such circuits in operation for some time.

In general, I am delighted to see that I stirred such a hot discussion. Personally I have no fixed ideas on anything, and am always ready to approach any proposition without prejudice. I even try to put aside prejudices which may have been brought about by my own experience. By temperament I am more interested in the future than in the past. But experience showed me that it is necessary to make extremely definite statements in order to bring about a discussion. It is necessary to put a stick of dynamite under some people before getting them to express any opinion at all.

First the objections to my questions. I expected objections. We all agree that the best way to arrive at definite conclusions is by obtaining definite operating data. I, therefore, jotted down some questions at random, including as many questions as I could think of that may have any bearing on the subject at all. I suggested to the chairman not to send these questions out for answers, but to submit the questions themselves for discussion. I expected that a discussion would eliminate some of my questions and add some other questions. The objections raised against some of my questions do not state that answers to them would not bring out any valuable information. It is only contended that answers to some of the questions would not be conclusive. Of course not. Even a set of answers to all the questions would not be conclusive. But out of an accumulation of data over a year or several years from various parts of the country, we would at least have something to analyze. Now we have nothing but opinions. Since the Committee has decided not to send out the questionnaire now, I hope that Mr. Sporn's Committee will soon be able to present an analysis of the answers to their questionnaire. I am sure that the chairman and members of the N.E.L.A. Committee will assist Mr. Sporn if they can do so.

The discussions by Mr. G. B. Kersey and Mr. R. E. Greene bring out the very significant fact that the two very important systems that they represent, on which continuity of service is as important as it can

possibly be anywhere, have recently been using the very simplest basic diagrams. I, therefore, flatter myself of being in exceedingly good company when I dare preach simplicity. They even go so far as to be satisfied with one single bus in some cases. I confess that I do not know of even one bus failure in my own experience. I only suggested that the second bus can be had generally at very low cost and may be convenient for splitting load or testing. But if important systems can get along with single buses, I am inclined to think that a second bus might be unnecessary in many cases where it is now used. My questionnaire, by the way, contains some questions in reference to bus failures.

I now come to the most difficult part of my concluding remark: the discussion by Mr. Philip Sporn. I am just coming to and find that my own first impression of being entirely knocked out is exaggerated. It is only a little black eye. Mr. Sporn has been giving this subject serious thought, has devoted a great deal of time to its study and has been the very active chairman of another committee, covering the same subject. Anything that he may have to say is, therefore, worth listening to with both ears. He agrees that breakers have been improved, but states that they still give trouble at times. No one said that they did not. And how about disconnects? Don't they ever give trouble? Don't the mechanisms or insulators ever fail? Don't the contacts ever fail? Is not a multiplicity of disconnects likely to give a multiplicity of trouble? Mr. Sporn claims that by-passes are operated a great deal, but fails to produce the so-much-needed proof that they are. He only refers to cases where breakers had to be reconstructed by being equipped with de-ion contacts or forced oil equipment. Such changes on breakers are not operating matters. They represent construction jobs. Is it advisable to provide multitudinous disconnects on every one of the hundreds of thousands of circuits in the country, disconnects that are precisely operating devices merely for taking care of future construction or reconstruction? And, again I ask, is it never necessary to replace or reconstruct disconnects, and do we provide by-passes for these disconnects and bypasses for the bypasses? As to the important loads that Mr. Sporn mentions that cannot be out for more than two seconds, I beg to refer again to the remarks of Mr. Kersey and Mr. Greene who certainly have loads on their systems of equal importance.

I must say that I cannot fully understand Mr. Sporn's objections to my suggestions that the tendency should be to make all circuits of a station or of a system alike and that emergency connections should be simple. In fact, he does not really object, he merely says that it is not always possible to do so. Of course it is not. But we can aspire to it; we can at least examine each case to see if it cannot be done. Personally I have always been opposed to rigorous standardization. It blocks progress, it hampers original thinking and inventing, it tends to lead to stagnation. But, - using Mr. Sporn's patent term, - I believe in rational standardization, which may be in the form of distilling our past experience and accumulated thoughts into simple principles - in this case basic diagrams - which must be subjected continuously to careful scrutiny and revision, and which could be used not as rigorous rules and autocratic laws, but as guides

and reminders. The straight road between two points is only seldom the first one discovered; only he who knows not the way of the explorer thinks that it is, and even after it is discovered, the straight road is not always the best road. But it is well to know that there is a straight road and where it is, and it is well to make sure that another more complicated road is better than the straight road in each individual case before embarking on a complicated road. It is in this sense and in this sense only that I threw out those basic diagrams. First of all I wanted to know if anyone can find other basic diagrams. At first I only had eight, but Mr. Harding, the chairman of this committee, produced three more, making a total of eleven. I am really disappointed to see that Mr. Sporn did not produce any more. Neither did the whole discussion. We can, therefore, reasonably assume that there are no others, and we have at least this much done.

I fail to see how anyone by any stretch of the imagination can interpret my remarks as expressing any criticism of operators. The operator's lot is a hard one; most operators are extremely competent, and it is often startling to find how resourceful they are in emergencies. Operators have plenty to do in emergency. They may even be excellent solvers of crossword puzzles, but I fail to see why anyone should expect them to solve any crossword puzzle during a condition of emergency. I know of extremely competent operators who after serving a number of years in the same places, did not know what certain switches were provided for by the designers, never having had any occasion to use them. In spite of the fact that I spent a year and a half on the drawing board as a diagram man, I could not be of any assistance to them, and Harry Hudini was already dead, so that I could not call on him for help. No, it was not even a black eye.

The new diagram presented in the discussion by Mr. H. B. Wood served well in many cases, better than some by-passes, but I am not quite ready to consider it basic because it is only applicable to definite cases. Mr. Wood's objection to the use of exciters for hydro auxiliaries is well taken, but I should prefer not to discuss it here, because I have been advised since writing the paper that another subject-committee is concentrating on the study of hydro-plant auxiliaries, and I shall take the liberty of bringing this point to the attention of the chairman of that committee.

The remarks of Mr. R. T. Henry are indeed very interesting, but all the points raised by him have already been covered above.

I fully subscribe to all the remarks made by Mr. D. M. Jones, but I also fully subscribe to the Ten Commandments and to the Constitution of the United States.

Mr. J. B. Adams' contention that with metal-clad switchgear there is less probability of a bus failure deserves serious consideration. His figure 12 is not basic because it refers only to the specific case of a regulator.

I believe that Mr. H. E. Ruggles correctly states the opinion of manufacturers of switchgear.

I agree with Mr. L. M. Smith that the safest man around electrical equipment is the one who does think and plan his movements, and I go a step further to say that most operators are such men. In fact I am opposed to the indiscriminate use of foolproof devices, because operators are not fools. But why burden them with unnecessary complications? They have plenty to do as it is. I am glad to see from Mr. Smith's remark that many companies are abandoning the use of stick switches and are replacing them by gang operated disconnects, since for many years I have been clamoring for a prohibition amendment against the use of stick switches. But the use of gang operated instead of stick switches should help in simplifying diagrams instead of making them more complicated.

I am somewhat disappointed at the absence of any important comment in relation to Figures 9 and 11 of the basic diagrams, and the insufficient discussion on the subject of auxiliaries. But on the whole I must say that the discussion has been very constructive. To the best of my knowledge this has been the first thorough open airing of the various questions connected with basic diagrams. It would be well indeed to continue the discussion.

FIG. 1

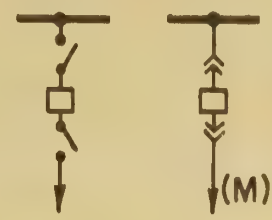

FIG. 2

FIG. 3

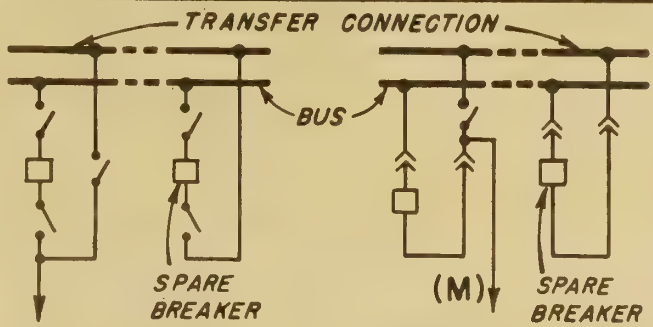

FIG. 4

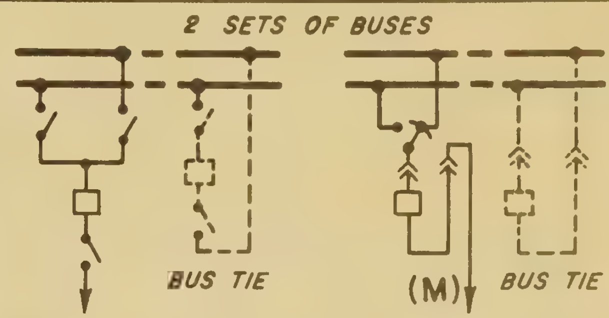

FIG. 5

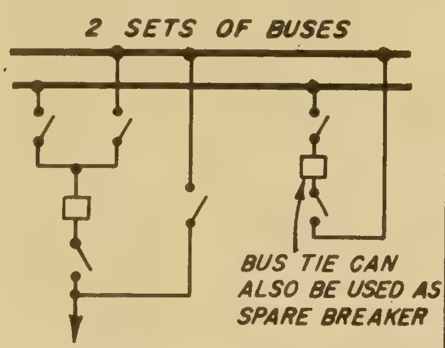

FIG. 6

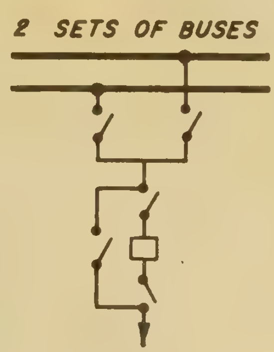

FIG. 7

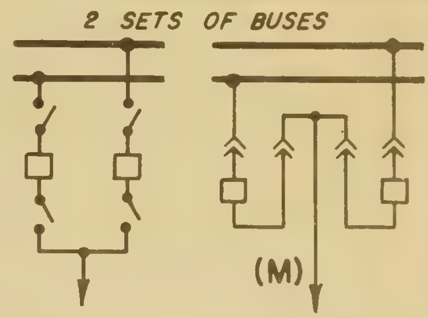

FIG. 8

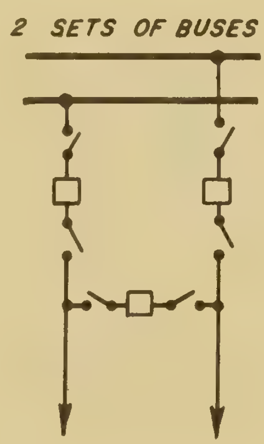

FIG. 9
(1½ BREAKERS PER CIRCUIT)

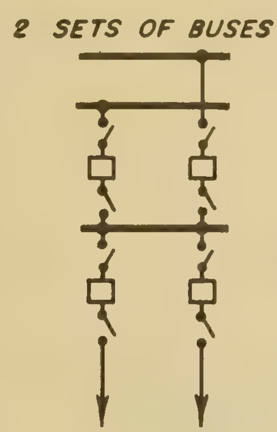

FIG. 10
(H – DIAGRAM)

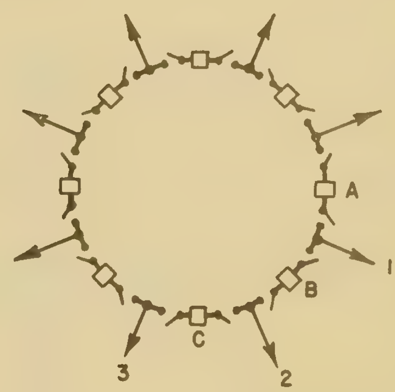

FIG. 11 (RING BUS)

BASIC MAIN ONE LINE CONNECTION DIAGRAMS

ELECTRICAL APPARATUS COMMITTEE
STATION DESIGN SUBCOMMITTEE
SUBJECT-COMMITTEE ON DESIGN FUNDAMENTALS

(M)-METAL-CLAD SWITCHGEAR

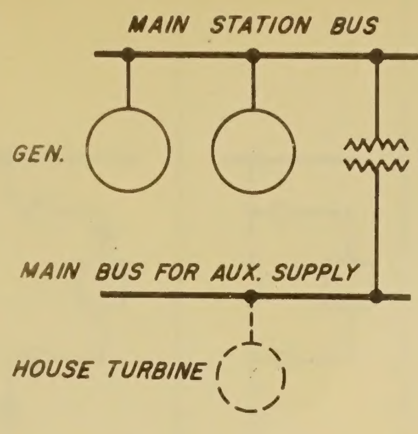

FIG. 12

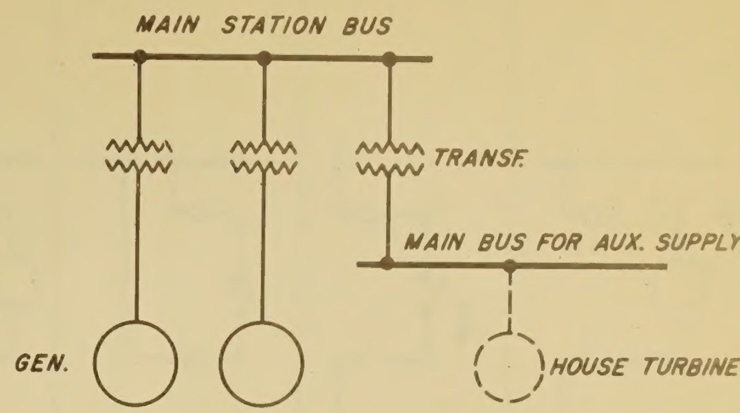

FIG. 13

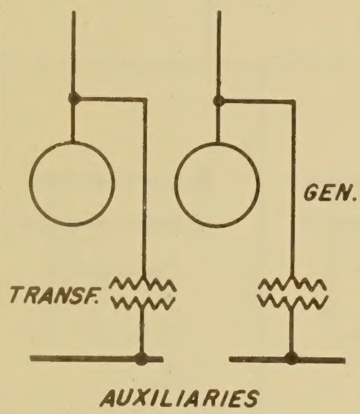

FIG. 14

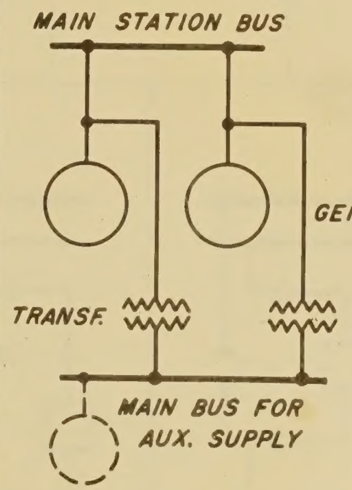

FIG. 15

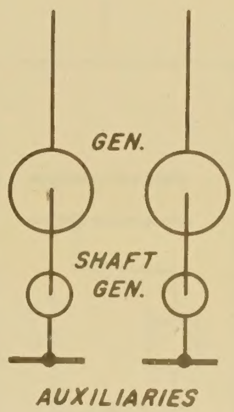

FIG. 16

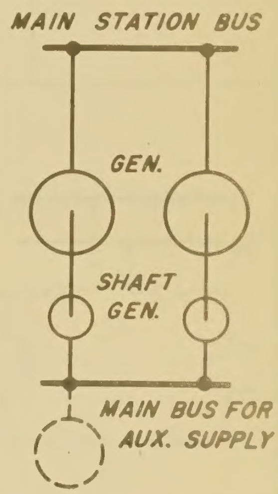

FIG. 17

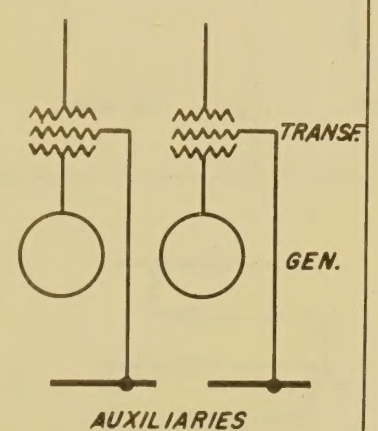

FIG. 18

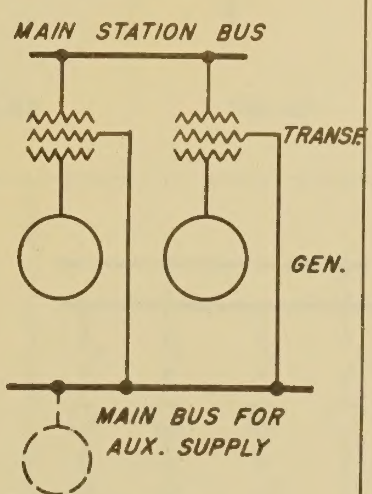

FIG. 19

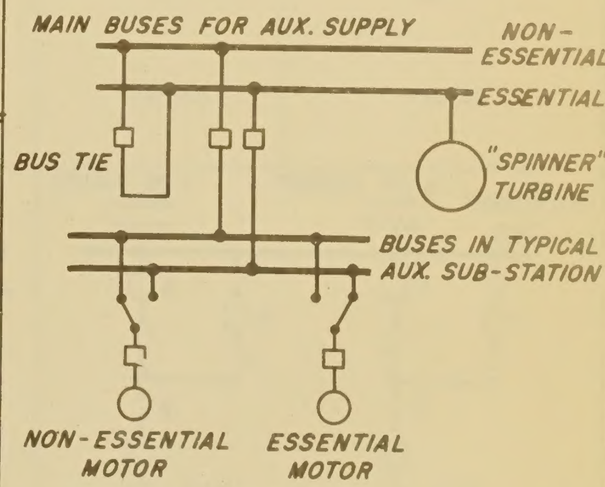

FIG. 20

BASIC AUXILIARY ONE LINE CONNECTION DIAGRAMS

ELECTRICAL APPARATUS COMMITTEE
STATION DESIGN SUBCOMMITTEE
SUBJECT-COMMITTEE ON DESIGN FUNDAMENTALS

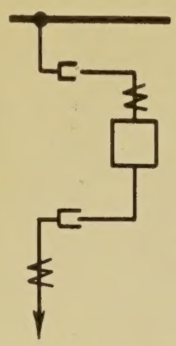

FIG. 21

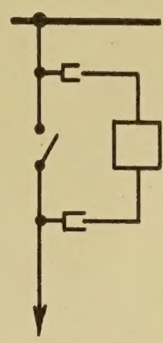

FIG. 22

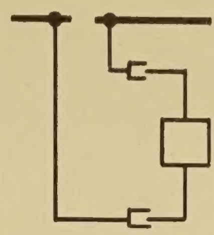

FIG. 23

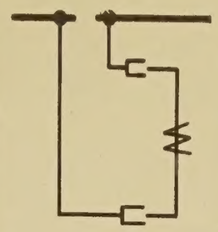

FIG. 24

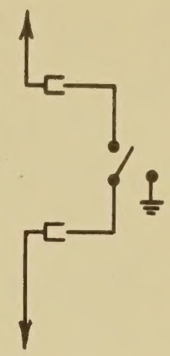

FIG. 25

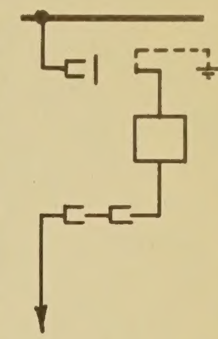

FIG. 26

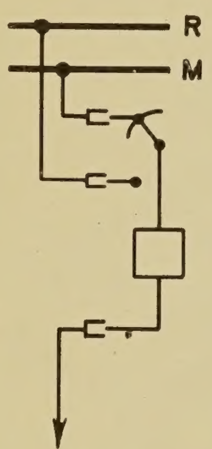

FIG. 27

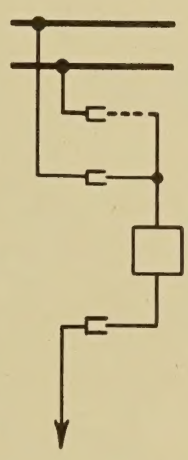

FIG. 28

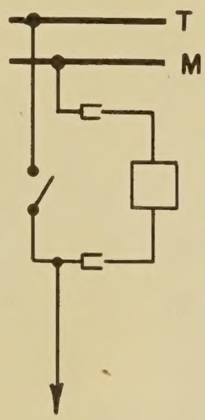

FIG. 29

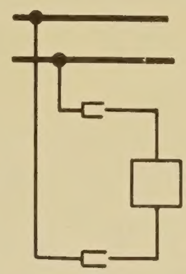

FIG. 30

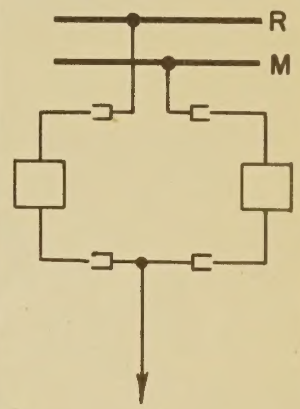

FIG. 31

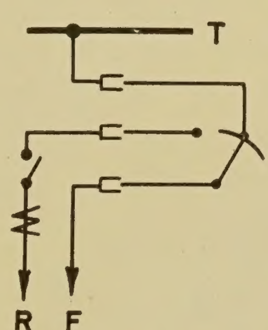

FIG. 32

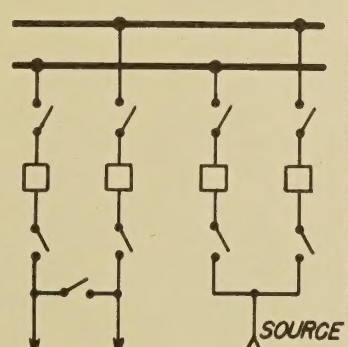

FIG. 33

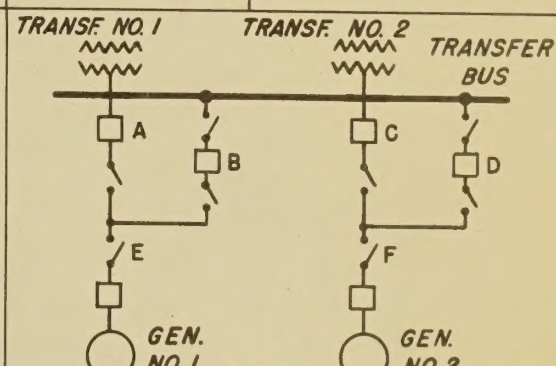

FIG. 34

UNIT ONE LINE DIAGAMS

METALCLAD SWITCHGEAR
ALLIS-CHALMERS REYROLLE TYPE
EXCEPT FIG'S 33 & 34